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OBSERVATIONS ON THE PATHOLOGY OF THE JACK PINE.

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INTRODUCTION.

A discussion of the fungous diseases of a particular forest tree is incomplete unless the general habitat in which the tree grows and which influences the occurrence and virulence of its diseases is considered. In general, a description of the characteristic home of the jack pine (*Pinus divaricata* (Ait.) Du Mont. de Cours.) is essentially that of the sandy plains in the region of the Great Lakes, where it attains its greatest size. Here the sand deposits are usually of great thickness and heavily mixed with glacial drift. The soil is composed chiefly of the same materials. With the exception of some of the lower plains and old lake levels the humus soil is very thin. In most regions within the range of the jack pine there is practically no humus. Where humus does exist in any appreciable thickness it is so much a part of the underlying sand and gravel that it dries out very rapidly, affording no opportunity for a luxuriant and uniform forest cover. Exceptions to this occur in parts of Minnesota and Canada. The improvement in the quality of the soil is at once reflected by the larger size of the jack pine and incidentally in the nature and virulence of the diseases attacking it. Observations show that a continuous and sustained growth in the case of the jack pine is not conducive to much injury from wood-destroying fungi.

Owing to the rapidity with which the soil of the jack-pine "plains" dries out and to the inflammable nature of the slight ground cover, favorable conditions are furnished for forest fires. This, in turn, likewise greatly influences the presence of fungous diseases as a result of injuries caused by the fires. Severe and rapid changes in temperature and a fluctuation of the mean annual precipitation are other factors characteristic of the jack-pine habitat. The susceptibility of forest trees, and likewise of the fungi attacking them, to the influence of soil and climate directly or indirectly produces conditions favor-

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able or unfavorable to the best development and spread of disease. The fungi inhabiting the bark and leaves are probably influenced by these factors in a far greater degree than are those attacking the heartwood.

Pathologically, the jack pine may be divided, in most regions of its range, into two forest types, which are determined largely by the amount of moisture in the soil. The fungi at work in the moist or swamp type may occur in the drier and more arid type, but may show considerable variation in the abundance of any one species. Another factor of considerable importance is the absence or presence of any associate tree of the type which may prove equally or even more susceptible to cosmopolitan fungi and thus increase the chances of infection for all members of the stand. In many parts of its range the jack pine occurs in pure stands. In mixture with other species it is usually attacked by a greater number of diseases than in pure stands.

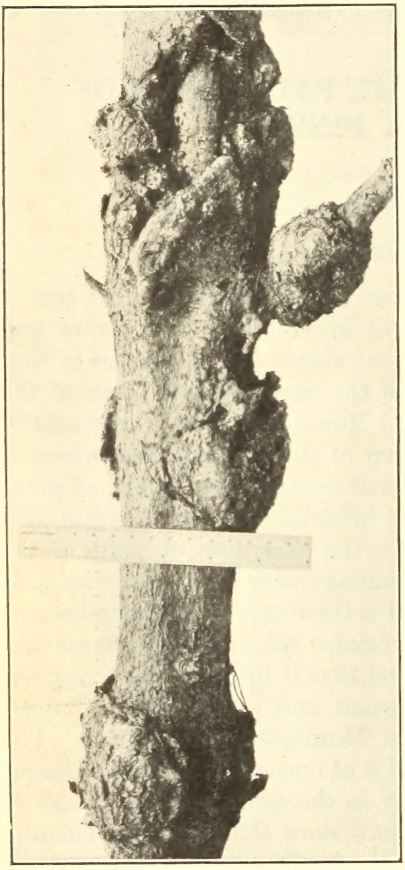

FIG. 1.—An 18-year-old jack pine infected with *Peridermium cerebrum*, showing the characteristic swellings which extend around the main stem.

DISEASES.

The fungus causing the greatest immediate injury to the jack pine of all age classes, as determined by pathological surveys in Michigan and Minnesota, is *Peridermium cerebrum* Peck (*Cronartium quercus* (Brondeau) Schrot.).[1] The galls (fig. 1) produced through the stimulative effect of the fungus are in May and June covered with globoid swellings somewhat after the manner of the convolutions of the

[1] *Peridermium cerebrum* is quite similar to *P. harknessii* Moore, which causes much damage to *Pinus contorta* (lodgepole pine) in the West. Some recent observations by Hedgcock and Meinecke indicate the possible identity of *Peridermium cerebrum* with *P. harknessii* on *Pinus radiata* (Phytopathology, vol. 3, p. 16, 1913). These two Peridermiums are held by Arthur and Kern to be identical (Mycologia, vol. 6, no. 3, pp. 133–137, 1914). Cultural experiments by Arthur and Kern (Mycologia, vol. 6, no. 3, pp. 133–137, 1914) and also by Hedgcock and Long (Journal of Agricultural Research, vol. 2, pp. 247–249, 1914) demonstrate the identity of *Peridermium fusiforme* with *P. cerebrum*. *Peridermium globosum* Arthur and Kern founded on a single specimen and supposed to occur on *Pinus strobus* has been acknowledged by the authors to be *P. cerebrum* on *Pinus divaricata*. The error arose from a misidentification of the host (Mycologia, vol. 6, no. 3, pp. 133–137, 1914).

brain—cerebroid. These blisterlike swellings are orange-yellow at first; after the rupture of the peridium and the dispersal of the golden yellow æciospores they become whitish. The gall formation causes great injury to the trunk and branches (fig. 1). The infection usually begins by means of some injury to the bark or cambial layer.[1] The gall swellings gradually increase from year to year from the growth of a perennial mycelium, so that they finally encompass the entire branch, resulting eventually, if the galls are near the trunk, in its death below and above the hypertrophy. Whether or not the entire branch dies depends upon the presence of lateral, leafed branches below the gall.

In dry sandy areas *Peridermium cerebrum* confines itself more generally to the branches, occurring rarely on the trunk but frequently in the axils of the branches. This latter condition usually results in a combination trunk and branch gall, which in numerous instances produces greater damage than either of the other two types of galls. The branch and trunk are girdled by abnormal wood tissue and are thus weakened (fig. 2). This results usually in either the branch or the tree being blown down by the wind. Personal observations show that borers and wood-rotting fungi entering at the burl often hasten the decline of the tree.

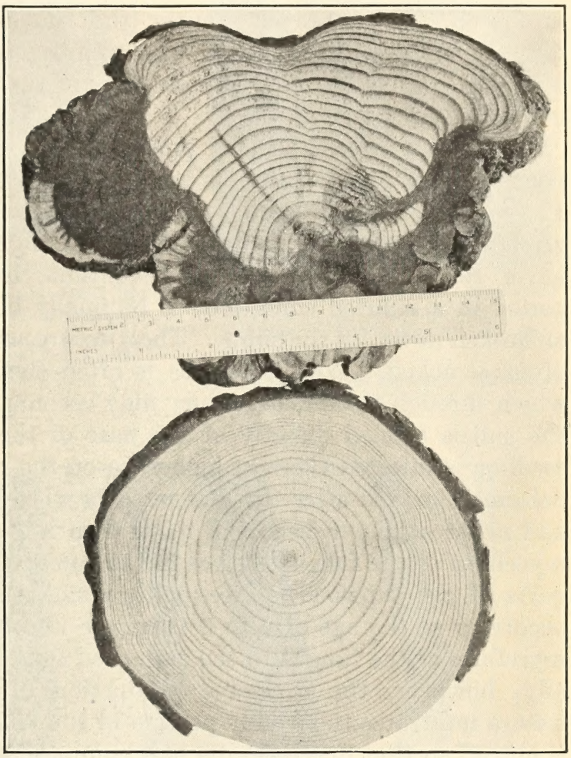

FIG. 2.—Cross sections of the main trunk of a jack pine heavily infected with *Peridermium cerebrum*. Note the progressive girdling by the resinous burl tissues in the upper figure and its effects on the increment of the trunk below, as shown in the lower figure.

From a careful examination of young twigs showing very recent infections at leaf scales, leaf traces, and at the bases of young pistillate

[1] Wounds made by sapsuckers, ovipositors of bark-stinging insects, rodents, and ice and snow breaks are common means of entrance for *Peridermium cerebrum*.

flowers, it is believed that *Peridermium cerebrum* can enter young seedlings or the tender portions of more mature growth without first having the bark broken. Entrance in this manner must, out of necessity, be aided by sufficient moisture for germination and to permit a rapid penetration by the young mycelium. On the sandy plains of the Great Lakes region rain water disappears almost immediately and the sand becomes heated about the isolated tree groups, causing a rapid evaporation from the surface of the trunk and branches and leaving the moisture content of the outer bark at a minimum. In whatever manner the fungus may enter its host, directly or through wounds, the number of galls and imperfect branches is usually much less on trees of the sandy barrens than in more moist regions.

In swampy areas the jack pine grows in close stands. Here the percentage of infected trees is much greater. The trunks of the 6 to 12 year old jack pines are often covered with swellings stunting the growth of the trees very rapidly (Pl. I, fig. 1). Trees so infected never reach maturity and may continue living for an indefinite period in a stunted condition, to be finally blown over by the wind or broken down by the snow. The 1 to 4 year old seedlings are quite often attacked. With these, as is often the case with larger trees which through mechanical injury may become infected at the ground, the gall is formed directly at the base of the main stem. When a seedling is infected there or higher up on the stem, it develops into a deformed growth after the manner of a witches'-broom (Pl. I, fig. 2) and never attains a height of more than 2 or 3 feet. The perennial mycelium of the fungus thrives in the cambial layer and in the living parts of the sapwood. Trees with a single infection on the trunk occurring at the age of 4 to 6 years are known to support the living mycelium of the fungus to the advanced age of 70 to 80 years. Usually, however, the excessive production of resin in the infected tissues infiltrates the woody portion of the trunk, and the sap supply is cut off so that death results in a comparatively short time (fig. 2). This is especially true in young seedlings. Peridermium galls are frequently observed a foot or more in diameter. Trees supporting galls of this size had succumbed in every instance to the disease.

Some knowledge of the damage done by *Reridermium cerebrum* to the jack pine may be obtained from notes of a pathological survey by the writer in the national forests of Michigan. Out of 100 trees of an average plat on dry sandy soil, not selected because of any pronounced diseased condition, 50 per cent were heavily infected, while only an occasional tree out of a second hundred on similar but moister soil was absolutely free from the disease. Out of 100 trees taken from the swamp type, practically all were infected. Not all the trees were infected seriously. A tree bearing a single branch gall

FIG. 1.—A 6-YEAR-OLD JACK PINE INFECTED WITH PERIDERMIUM CEREBRUM.

The complete girdling of the main stem by two oppositely arranged galls is shown. Note the wedge-shaped gall tissues.

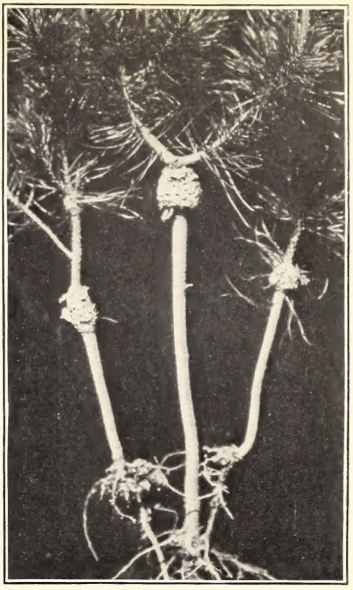

FIG. 2.—FOUR-YEAR-OLD SEEDLINGS OF JACK PINE, SHOWING THE CHARACTERISTIC SWELLINGS OF PERIDERMIUM CEREBRUM.

The entire crown of the seedlings develops into spherical brooms.

FIG. 3.—VARIOUS TYPES OF INFECTION OF YOUNG JACK PINE BY PERIDERMIUM COMPTONIAE.

Note that in the central figure the fungus has invaded the underground tissues of the stem.

was marked "infected." Four trees specifically studied yielded by actual count an average of 220 burls on the branches and 13 on the trunks. The cones produced by these trees, although of average number, were small, with a higher percentage of abortive sporophylls than is commonly the case with this species (fig. 3). Comparative germination tests of seeds from heavily infected and vigorous non-infected jack pine of the same age and type conditions showed for the former a germination of 19 per cent below that of the latter. For this experiment 10 samples, consisting of a dozen or more cones, were taken from each of five heavily infected and five uninfected pines. Fifty seeds from each of these samples were planted in sand, kept moist with distilled water, and allowed to stand at laboratory temperature (about 70° F.) for 90 days.

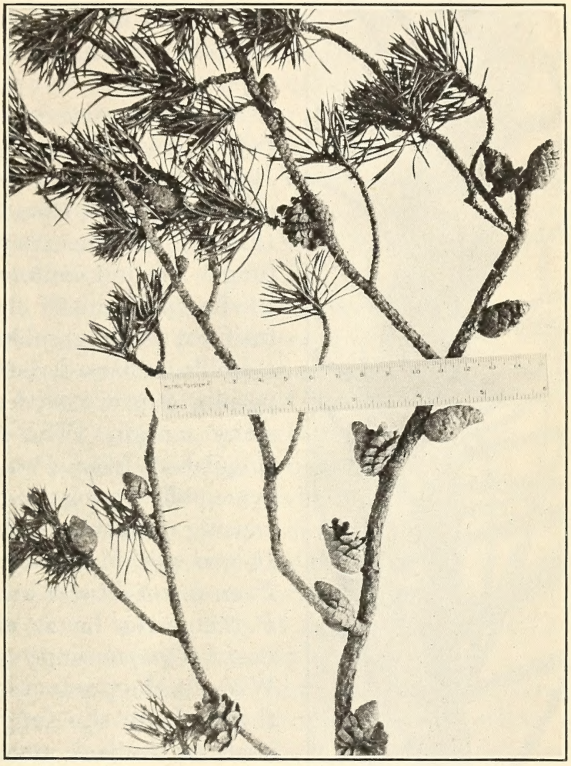

FIG. 3.—Branch of jack pine with aborted cones, the result of a severe attack of *Peridermium cerebrum*. Note that some of the cones did not open and that most of them are less than an inch in length. Average normal cones measure from 1½ to 2 inches.

The prolific development of *Peridermium cerebrum* in many parts of the jack-pine forests of the Great Lakes region is a factor in reforestation which should be carefully considered. The fact that the fungus occurs so commonly on young seedlings in the natural forest and occasionally in the nursery shows that it is a menace to the best development of the species. The largest and best formed jack pine in all the regions studied where the Peridermium was abundant was almost entirely devoid of this injurious disease. However this may be interpreted as to the original differences in vigor, the fact that heavily infected trees were invariably scrubby and ill formed is, in the mind of the writer, directly referable to the effects of the parasite. The fact that *P. cerebrum* has its telial stage on the leaves of several

species of Quercus [1] should be of much significence in control work. *Quercus velutina* and *Q. coccinea* are two scrub oaks frequently forming a conspicuous part of the jack-pine type, particularly in Michigan. Methods could be devised for the eradication of these worthless species, thus removing the alternate host of the fungus. However impracticable this may be on a large scale, in wood lots and small holdings this would not be a very difficult matter. The removal of infected branches of young growth could be done in the orchard-like stands of jack pine on the more sandy soils, thus saving many young trees from early suppression.

FIG. 4.—Young jack pine infected with *Peridermium comptoniae*. Note the ruptured peridia with their serrate margins.

In a few instances, in the region studied, young jack pine was found to be diseased by *Peridermium comptoniae* (Arthur) Orton and Adams (*Cronartium comptoniae* Arthur). (Fig. 4.) In the experience of the writer this fungus was not common. The æcial stage of the fungus is chiefly characterized by a slight fusiform swelling, seldom forming the spherical galls so characteristic for *P. cerebrum*. The peridia rupture with a sharply serrate or spiny margin. The fungus is further distinguished from *P. cerebrum* by attacking principally young seedlings (Pl. I, fig. 3) and causing excessive brooming of the branches. It was not found on more mature growth. *P. cerebrum* attacks both young and old trees. *P. comptoniae* has its alternate stage on sweet fern [2] (*Comptonia peregrina* and *Myrica gale*). Without the production of the teliospores on these plants the fungus can not reproduce itself on the jack pine.

As a precaution agains tthese Peridermiums entering the forest nursery and the possibility of their transportation to other regions, all alternate hosts, such as species of oaks and sweet ferns, should be removed from the vicinity of the nursery. This immunity zone should be extended as far back from the nursery as time and means will allow. Before new nurseries are established a pathological survey of the immediate region should be made as to the presence of these heterœcious pine rusts. Much attention should also be given

[1] Demonstrated by Dr. C. L. Shear, Jour. Myc., vol. 12, p. 89, 1906.

[2] Demonstrated by G. P. Clinton, Conn. Agr. Exp. Sta. Rept., 1907, pp. 380–383, 1908.

the selection of nursery sites, with regard to the topography and prevailing winds of the region.

With the exception of *Peridermium cerebrum* and *P. comptoniae*, few fungi of economic importance attack the living jack pine in the drier parts of its range. On the dry pine barrens of the Lake States the jack pine reaches its normal age without much defect in the wood arising from fungous diseases, although exceptionally old trees of 90 years and more frequently show considerable decay. In mixture with other species in the more moist regions of its range, particularly in parts of northern Minnesota and of Canada, *Trametes pini* (Brot.) Fr. causes considerable heart-rot in trees of 60 years and older. In general, however, this fungus is in negligible quantities. In close stands jack pine prunes readily during its most rapid growing period, forming straight clear stems. The rapid occlusion of the branch knots shortens the danger period for infection by wound fungi. It is principally due to this fact that some of the most serious wood-destroying fungi do not effect an entrance until the tree has reached its period of decline.

Polyporus schweinitzii Fr., causing a butt rot, is usually in greater abundance than *Trametes pini*, but the percentage of infected trees, even on the more protected soils, is seldom more than 2 to 4 per cent of the stand. The jack pine is a deep-rooted species and unless the root system comes in contact with a hard stratum of clay and gravel, root-destroying fungi are largely a negligible quantity. In this class are *Fomes annosus* Fr. and *Armillaria mellea* (Vahl.) Quél., which very rarely occur on the jack pine. Only a few isolated and unimportant infections have ever been recorded by the writer.

The jack pine does not suffer any material injury from needle fungi. Those that do occur are mostly of a saprophytic nature. *Lophodermium pinastri* Schrad. is found only occasionally.

On dry soils in open stands the jack pine frequently shows a tendency to form witches'-brooms. The terminal shoot, which is the part usually affected, develops into a thick-matted broom, precluding any further growth in that direction. Trees thus infected usually show a rapid falling off in increment, probably dating from the time when the influence of the parasite was first felt. Another type of broom formation is confined to the lower and older branches and has a similar effect on the growth of the host. These brooms are probably caused by some perennial fungus. In the absence of any fruiting structures the causal organism can not be determined.

The jack pine in its eastern range is not subject to mistletoe injury. Macoun [1] reports the occurrence of *Razoumofskya americana* (Nutt.) Kuntze, the lodgepole-pine mistletoe, on the jack pine in Canada.

[1] Macoun, John. Catalogue of Canadian Plants, pt. 3, p. 422. Montreal, 1886.

The writer finds this mistletoe to be the cause of serious damage to the jack pine at its most western extension or where it approaches the zone of the lodgepole pine in the north.

SAPROPHYTIC FUNGI.

Aside from the previously mentioned wood-destroying species, which in many cases continue alive after the death of the host,[1] the usual strictly saprophytic fungi of coniferous woods are found on cut or fire-killed jack pine. *Ceratostomella pilifera* Fr., the blue-stain fungus, appears very rapidly after the death of the tree. In moist situations, species of Auricularia and Dacryomyces are surprisingly abundant, but can be of little importance, as the mycelium does not penetrate the wood to any appreciable distance. The first fungus of importance is *Polystictus abietinus* Dicks. This is a sap-rotting species and is seldom absent from fire-killed trees after the second or third year. Second in importance is *Lenzites sepiaria* Fr., which works both in the sap and in the heartwood and usually appears on the fallen trunks after they have lain for three or four years, following up the first-mentioned fungus. The Lenzites appearing on jack pine is invariably the true, small, thin-fruited form, with radiating gills. *Lenzites sepiaria* is as easily recognized by the orange-yellow color of its growing margin as the young, growing *Polystictus abietinus* is by its beautiful purple tinge. *Fomes pinicola* Fr. has very little to do with the decay of fallen jack pine. This fungus has not been found to be very common. *Polyporus palustris* Berk. and Curt. occasionally appears, but is more common on dead Norway pine. *Fomes carneus* "Nees" very rarely occurs on jack pine. *Lentinus lepideus* Fr., *Polyporus sulphureus* Fr., and *Trametes sepium* have been collected by the writer on dead jack pine, but they are very rare. Resupinate Thelephoraceæ occur only in the moist stands of mixed species. Those which may be considered of importance in the decay of fire-killed timber in the forest are *Corticium byssinum* (Karst.) Burt., *C. sulphureum* Pers., *C. galactinum* (Fr.) Burt., *Coniophora olivaceae* (Fr.) Bres., and *Peniophora globifera* E. and E. A yellowish white Poria which goes under the name of *P. subacida* Peck is occasionally found on fallen jack pine in Minnesota. This fungus has been observed by the writer in a fruiting condition on old boxes and barrel staves made from newly felled living trees. This indicates its probable parasitism on jack pine in the living forest.

[1] This is a fact that is not generally appreciated, and on it depends the solution of some very important pathological problems in the forest. Vigorously growing sporophores of *Trametes pini* springing from original infections in the living tree have been collected from a fallen western larch which had lain on the ground for more than 100 years. This was determined by the age of a western red cedar growing astride the fallen trunk. Practically all the more serious wound and root fungi of the genera Trametes, Fomes, Polyporus, and Agaricus in moist situations continue alive indefinitely after the death of their hosts.

INJURIES DUE TO OTHER CAUSES.

In the absence of an adequate snow protection on the flat wind-swept pine barrens of the Lake States, winter injury sometimes results to young growth from long exposure to freezing temperatures. Winter-injured seedlings of jack pine, however, recover more rapidly than those of the more sensitive associate species and when in this condition are not so apt to be attacked by secondary deteriorating agents. It has already been stated that the deep root system of the jack pine is unfavorable to some root-destroying fungi. In like measure this is a safeguard against injury by wind. It is very unusual to find jack pine blown down by the wind when the trees are in a healthy condition. Very old trees sometimes succumb to strong winds, but it is found that such trees are usually mechanically weakened by wood-destroying fungi. The jack pine may be considered very windfirm. Porcupines and squirrels are known to do considerable injury to jack pine during the winter months when food is scarce. The latter animal is much addicted to gnawing the galls of *Peridermium cerebrum* in the spring during the period of the exudation from the diseased bark of a sweet yellow liquid which bears the conidiospores of the fungus. Since squirrels also gnaw the galls when the æciospores are mature, they may be considered a factor in the distribution of this fungus. The bark of the galls is frequently completely gnawed away, killing the infection.

In general, the jack pine is very sensitive to fire, which usually causes the greatest injury in the typical dry sandy jack-pine plains. In many cases fire injury in jack pine results from repeated burnings, the tree having successfully withstood the first slight ground fires. Fires in the more typical jack-pine forests pass through very quickly, so that the thickened bark immediately at the base of the tree affords sufficient protection until it is burned off by succeeding fires, which frequently occur notwithstanding the meager ground cover. The fact that the species frequently grows in orchardlike stands or in isolated groups, more or less separated from one another by free areas, greatly lessens the damage of the fire spreading from one group to another. However, the low-spreading branches, which often extend to the ground, increase the danger from crown fires.

CONCLUSIONS.

With reference to the prevalence and severity of its fungous enemies, two distinct forest types for the jack pine may be recognized: The pure dry sandy-plain type and the mixed type of moist protected soils.

The most important fungous disease of the jack pine is *Peridermium cerebrum* Peck, the control of which in many localities is quite a serious

forest problem. The fungus attacks all age classes, causing the death or early suppression of trees of tender years and seriously interfering with the propagation and development of more mature growth.

From the standpoint of merchantability, wood-destroying fungi in the living tree are in almost all regions a negligible quantity. The two most important are *Trametes pini* (Brot.) Fr. and *Polyporus schweinitzii* Fr. These, however, do not produce any appreciable decay till after the tree reaches its period of decline, which is attained after a comparatively rapid early growth. This period may be placed approximately at from 60 to 80 years.

The wood of dead jack pine rapidly deteriorates under the influence of a number of saprophytic fungi and may not be expected to remain sound in the forest for more than two or three years.

Jack pine is sensitive to heat, but suffers only occasionally from winter injury.

Because jack pine in general is comparatively free from a number of the diseases which are common on other conifers and is resistant to drought, winter injury, and frost, it is admirably suited for reforesting many of the dry sandy regions of the North-Central States.

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